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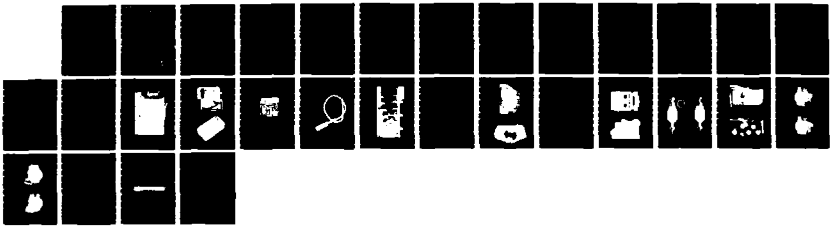

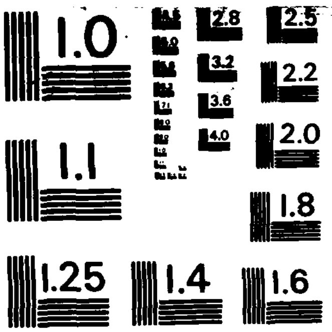

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IMPROVEMENTS TO HIGH SPEED ROTATING PRISM CAMERAS INCLUDING ON BOARD TIMING AND EVENT PULSE GENERATORS

Kenneth J. Lee

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ABSTRACT

Details of modifications incorporated in a Hycam rotating prism high speed camera are reported here. The modifications, adaptable to most high speed cameras, include remote DC starting, an on board timing light generator and an event pulse generator. These and other modifications described have improved the performance, reliability and ease of operation of high speed cameras both in the laboratory and in the field.

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IMPROVEMENTS TO HIGH SPEED ROTATING PRISM CAMERAS INCLUDING ON BOARD TIMING AND EVENT PULSE GENERATORS

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ABSTRACT

Details of modifications incorporated in a Hycam rotating prism high speed camera are reported here. The modifications, adaptable to most high speed cameras, include remote DC starting, an on board timing light generator and an event pulse generator. These and other modifications described have improved the performance, reliability and ease of operation of high speed cameras both in the laboratory and in the field.

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CONTENTS

IMPROVEMENTS TO HIGH SPEED ROTATING PRISM CAMERAS INCLUDING ON BOARD TIMING AND EVENT PULSE GENERATORS

1. INTRODUCTION

Field testing of ordnance provides a severe environment for the operation of photographic equipment, particularly high speed camera systems. There are problems with fire, blast, fragmentation, dust, moisture and operating from portable generators that are not normally encountered in the laboratory. It is against this background that the following improvements to photo-instrumentation in the Explosives Instrumentation Group (EIG) at MRL have been developed and field tested.

1. A self contained remote camera controller with status indicators.

2. A modified remote start circuit using an opto-isolator for low voltage control.

3. An on board 1 kHz crystal controlled timing mark generator driving an improved light emitting diode (LED) timing light.

4. An on board event mark generator driving a LED.

5. A modified Hycam commutator resulting in increased motor life and reliability, particularly when operating at maximum speed.

6. The number and type of connectors on the Hycam camera reduced for more convenient operation.

Although these improvements were designed primarily for the Hycam rotating prism high speed camera manufactured by Red Lake Laboratories, most can be readily adapted and applied to other high speed cameras. For example a

Stalex M16A high speed camera has also been fitted with a LED timing light and on board timing mark generator as well as being modified for operation by the remote controller.

As a result of these improvements not only has increased reliability and simplicity of operation been achieved but also improved systems flexibility and compatibility with other forms of electronic instrumentation.

2. REMOTE CAMERA OPERATION

2.1 Background

In the field our "Hycam" high speed cameras are generally started remotely from a control point, which is typically 200 m distant from the cameras, by energising a 240 V AC relay in the camera. The remote control cable often has joins or connectors which moisture may penetrate, and has been known to cause premature and undetected operation of the camera. These cameras have an "event" microswitch which makes contact when the film has run a preset distance; this closing contact is often used to trigger the detonator firing circuit and to synchronise other instrumentation. The contacts remain closed until the camera door is opened or a new film loaded. Therefore a premature undetected camera run could cause the detonator to fire the instant the firing unit was energised, resulting in the loss of the high speed film record and probably results from other instrumentation as well. Clearly a remote control incorporating camera status is essential.

It is often required to operate two or more high speed cameras simultaneously and as these cameras can draw 30 A at 240 V AC we generally operate each camera from a separate 10 kVA generator. A conventional Hycam uses a 240 V AC electromagnetic start relay for remote operation. Closing the remote start switch energises the camera start relay. If two Hycam remote start cables share common poles of the remote start switch their respective start relays either do not latch, or "chatter" due to the unsynchronised mains voltages of the two generators being connected together, via the start relay coil of each camera.

The above problems stimulated the development of an improved method of remote camera operation. The method developed has been in use for some time and incorporates an opto-isolator in place of the original 240 V AC start relay (Fig. 3), allowing any number of cameras to be operated simultaneously. Remote control is now achieved from a single compact hand held controller with status indicators.

2.2 *Remote Camera Controller - Operation and Circuit Description*

To avoid the possibility of the camera being switched off prematurely, which can result in film breakage and loss of recording, an automatic controller has been designed and extensively tested. The circuit diagram is shown in Fig. 1.

When the start button is pressed the current drawn by the camera opto-isolator (PC-1) is sensed by another opto-isolator (PC-2) in the controller which, via its output transistor, energises RL1 which in turn latches the 9 V DC supply to the camera. The camera "run" LED indicates to the operator that the control 9 V DC is latched to the camera. When the camera has completed its run it returns a 9 V square wave signal, via the same coaxial cable, to the controller. This "end of film" signal is supplied by the "555" oscillator circuit (Fig. 2 and 3) fitted in the Hycam and is switched by an additional microswitch (S2) mounted in parallel with the existing motor turn off switch. When this switch is actuated it disconnects the 9 V DC energising signal and connects instead the 9 V "end of film" signal. In the controller the "end of film" signal is coupled through capacitors C1 to C4, a rectifying circuit and the "end of film" LED indicator to the negative side of RL1. This DC voltage reduces the potential difference across the relay sufficiently to de-energise it, thereby releasing its latched contacts from across the push-button "start" switch, turning off the 9 V DC energising signal to the camera.

The current sensing method of starting was adopted to avoid discharging the battery if the start push-button was inadvertently pressed with no load connected to the controller. It should be noted that this method is not suitable for stop/start operation; however most high speed cameras, such as the Hycam, cannot operate in this mode. Fig. 4 shows internal and external views of the camera controller and Fig. 5 provides details of the printed circuit board and component layout.

3. TIMING MARKS

3.1 *Background*

To allow time measurements to be made from a high speed film, which may have been accelerating through the film gate from start to finish, timing marks are exposed onto the edge of the film by pulsing a neon lamp or LED at a known frequency, usually 1 kHz. The original LED supplied with the Hycam high speed cameras needs a peak driving current of 1.5 A to mark the film at high framing rates. At this current the LED cannot operate continuously and it is desirable that it operates only for the duration of the camera run. To achieve this it was necessary to have the LED signal generator situated at the control point so that it could be switched on just before, and off just after operation of the camera. When driving the LED over cables in excess of 200 m cable resistance limited the current to less than the maximum with consequent loss of timing mark density on the film which was barely adequate at high framing rates anyway.

3.2 Timing Mark Generator

3.2.1 General Description

To overcome the problems outlined in 3.1 a compact, crystal controlled 1 kHz timing mark generator has been designed. This generator is fitted into the optical head of the Hycam high speed camera and takes power from the existing 25 V DC camera supply. The new timing mark generator drives a HP 5082-4658 high efficiency LED fitted in place of the original low efficiency high current LED supplied with the camera. Unlike the original LED the 5082-4658 can operate for long periods without damage due to overheating. In addition the new system offers a considerable cost saving compared with the price of Hycam spare parts.

The new timing mark generator has two selectable output currents to suit colour and black and white films. The LED timing light is focussed onto the edge of the film by a cylindrical glass lens mounted in an aluminium holder (Fig. 6) with the resultant timing marks being approximately rectangular in shape (Fig. 7). Tests have shown that dense timing marks are produced on the film edge when operating at maximum framing rate and with normal film processing even in the streak mode. Considerable field testing has shown this system to be highly reliable.

3.2.2 Circuit Description

The circuit diagram is shown in Fig. 8. The integrated circuit IC1 (CD 4060B) is the crystal oscillator and divider section. It divides the 4096 kHz crystal frequency by 2^{12} thus producing a 1 kHz square wave, which is differentiated and used to trigger IC2 a (Type 555 timer). The timer is used as a pulse generator and current driver providing a 15 μs current pulse to drive the LED via suitable current limiting resistors (for colour and black and white film).

Power for the circuit is obtained from the existing 25 V DC camera supply which is regulated by IC3 to 15 V DC. The LED LD1 and LD2 indicate which marker intensity has been selected. Because these LED are connected in series with the film marking LED a positive indication of timing light operation is provided without opening the camera

Fig. 9 shows the printed circuit board and component layout. Fig. 10 shows the circuit mounted in the Hycam optical head and Fig. 7 shows photographic examples of timing marks.

4. EVENT MARK GENERATOR

4.1 Background

Most high speed cameras, including the Hycam, are fitted with an event light focussed onto the opposite edge of the film to the timing light. This light can be energised to produce an event mark on the film corresponding in time with important off camera events which, when the film is analysed provide temporal correlation with those events. For example an event mark is often produced simultaneous with detonator firing. An improved on board event pulse generator driving a high efficiency LED has been developed.

4.2 Circuit Description

The circuit diagram is shown in Fig. 11. A 90 V positive trigger pulse is applied to the input of the event mark generator circuit. This pulse is divided and capacitively coupled to the gate of the silicon controlled rectifier (SCR 1). The SCR discharges C1 through current limiting resistors and the event LED causing the LED to flash. The current limiting resistors are selected by switch S1B allowing low or high intensity marks to be selected for colour or black and white film respectively. A 90 V trigger pulse is used for compatibility with EIG firing equipment which is designed to have an insensitive trigger input. Therefore a 90 V positive pulse capable of driving a 75 Ω input impedance is used to ensure noise immunity. Of course the event mark generator input sensitivity can be varied by simply altering the input divider resistance valves.

The event mark generator is incorporated on the same printed circuit board as the timing mark generator (Fig. 9) which allows it to be fitted inside an existing Hycam optical head.

4.3 Mechanical Modifications to Hycam to Accept New Event LED Assembly

In order to install an event LED/lens assembly to the existing latch block the following modifications need to be made.

1. The original neon event light hole is enlarged to 6.3 mm to accept the new LED/lens assembly. This hole is drilled at the same angle and concentric with the original smaller hole (Fig 12). In later model cameras using a LED event light the hole would not require enlargement.

2. A 3 mm grub screw is used to clamp the LED/lens assembly in place (Fig. 12).

3. The new hole is deburred and blackened to minimise light reflections.

5. MOTOR COMMUTATOR MODIFICATIONS

Most high speed photography carried out in EIG is done at the maximum framing rate of about 9000 frames/s (full frame). After several years this level of operation caused several of the Hycam motor commutator segments to separate from the base material.

As replacement commutators are very expensive it was decided to repair the faulty commutators. The commutator segments were first carefully re-positioned and then glued in place with an epoxy resin adhesive. After the epoxy had cured the commutator was lightly machined in a lathe to remove any high spots. To avoid a recurrence of segment separation a retaining collar manufactured from "Tufnol" was glued in place around the commutator using epoxy resin adhesive (Fig. 13).

Commutators modified in this way have now had considerable use running at full speed. A recent inspection showed no signs of commutator segment separation, confirming the success of this modification.

6. CHANGES TO CAMERA CONNECTORS AND SWITCH

6.1 Background

Most cables use on field trials conducted by EIG are coaxial, terminated at each end with BNC crimp connectors. These cables are cheap and if damaged are easily replaced or repaired. Therefore, whenever possible, camera connectors have been replaced by BNC coaxial connectors, thus eliminating the need for special cables with unique connectors (Fig. 14).

6.2 Event Output Socket

The original Hycam provided dual event outputs through a three pin socket to both the normally open and normally closed contacts of the event microswitch (Fig. 15). Experience showed that only the normally open mode was used and therefore the old camera event connector has been replaced by a single isolated BNC socket connected to the normally open contacts.

6.3 Remote Start Socket

The original three pin Cannon remote start connector has been replaced with an isolated BNC coaxial socket. This was made possible by the introduction of the new remote camera controller (2.2).

6.4 *Timing Light Socket*

The two pin Amphenol timing light signal input socket became redundant when the on board timing mark generator (3.2) was installed. As a result it was removed and replaced by the timing/event light intensity selection switch.

6.5 *Event Light Socket*

The two pin Amphenol event light signal input socket was replaced with an isolated BNC coaxial socket.

6.6 *Camera Start Switch*

The camera start toggle switch was made redundant by the introduction of the new remote camera controller (2.2). It was therefore removed and a red neon indicator lamp fitted in its place as a 240 V AC power indicator (Fig. 16).

7. SUMMARY

The modifications described in this report have proved effective both in the laboratory and in the field enabling high speed cameras to be easily integrated into trials instrumentation systems. In particular the low voltage controller has simplified remote control. The low voltage now used to start the cameras is more compatible with the signals produced by other instrumentation. The on board timing light generator provides set and forget convenience and most importantly timing marks of vastly improved density capable of marking the film in the framing and streak modes.

8. FUTURE DEVELOPMENT

EIG field trial instrumentation is currently being converted to use the IEEE-488 instrumentation bus. As the Hycam High Speed Cameras are part of this instrumentation, a bus interface to serial line driver is being designed for Hycam control. It is envisaged that the status of any camera (speed setting, power on, film position etc.) will be obtained remotely, using the IEEE-488 bus controller, before detonating a charge. The controller will compare the camera status with preprogrammed parameters then decide accordingly if the firing sequence should proceed.

When more than one Hycam is used all cameras will be connected by one coaxial cable (or twisted pair wire) in a "daisy chain" fashion. Each

camera will contain an addressable UART (universal asynchronous receiver transmitter) and will be sequentially interrogated by selectively addressing each unit in turn. This system will also reduce the cable requirement further by allowing the event and start signals to use the same cable.

Although the Hycams will have IEEE-488 bus compatibility they will still retain their present start/event system for simple close control camera only operation.

9. ACKNOWLEDGEMENTS

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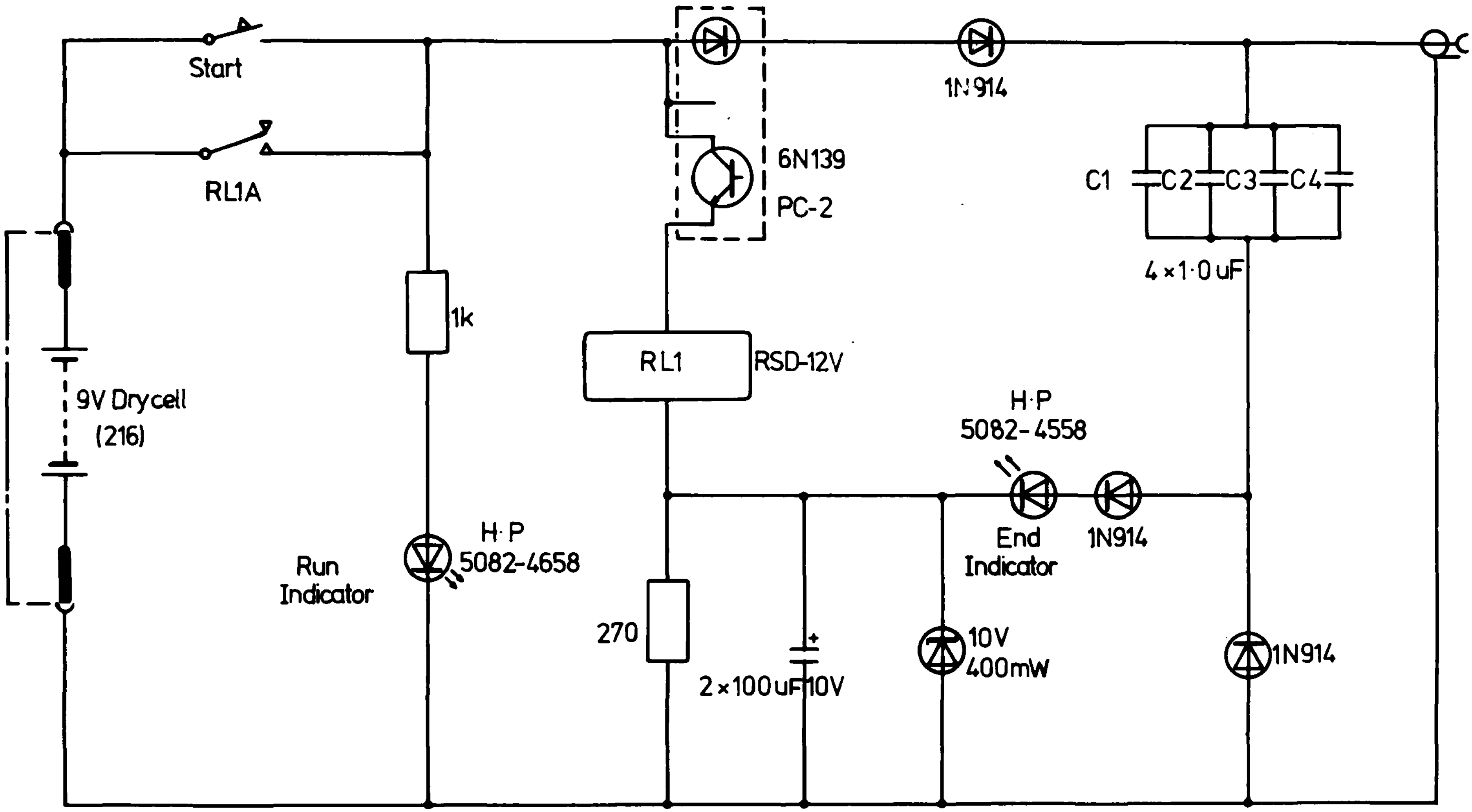

FIGURE 1 - Camera Controller Circuit Diagram.

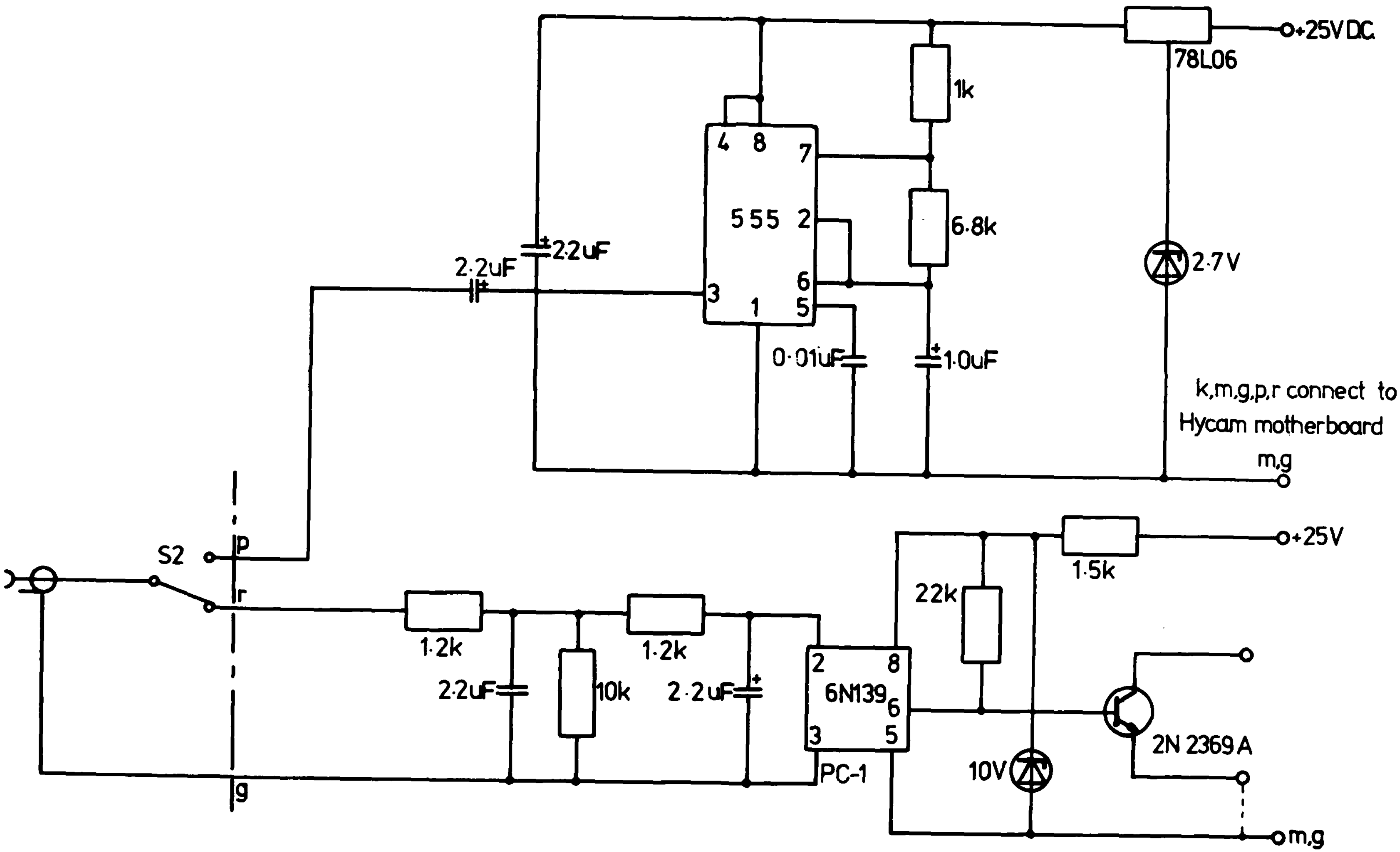

FIGURE 2 - End of Film Oscillator and Remote Start Circuit Diagram.

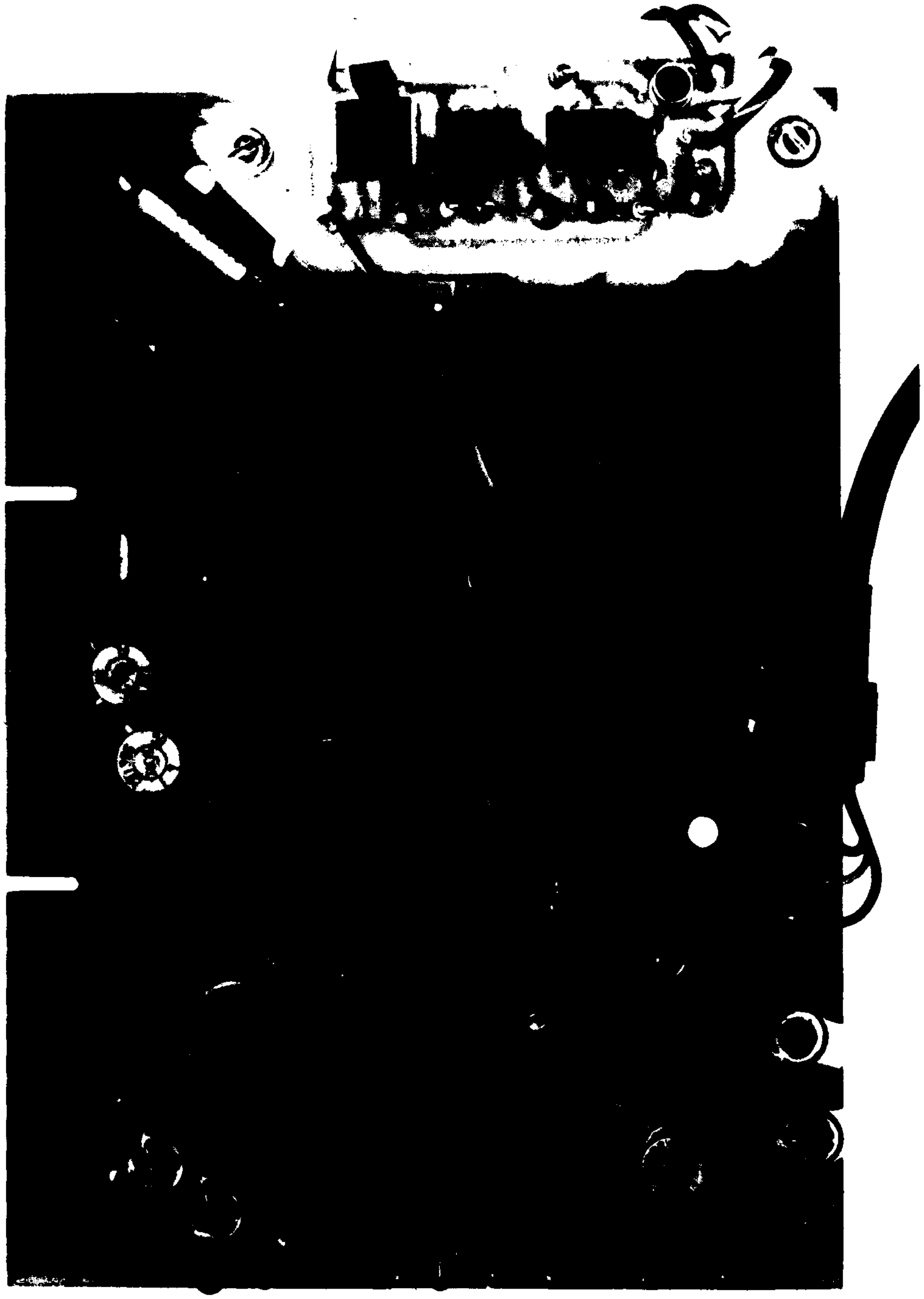

FIGURE 3 - Hycam motor speed regulator board with additional opto-isolator remote start circuit highlighted.

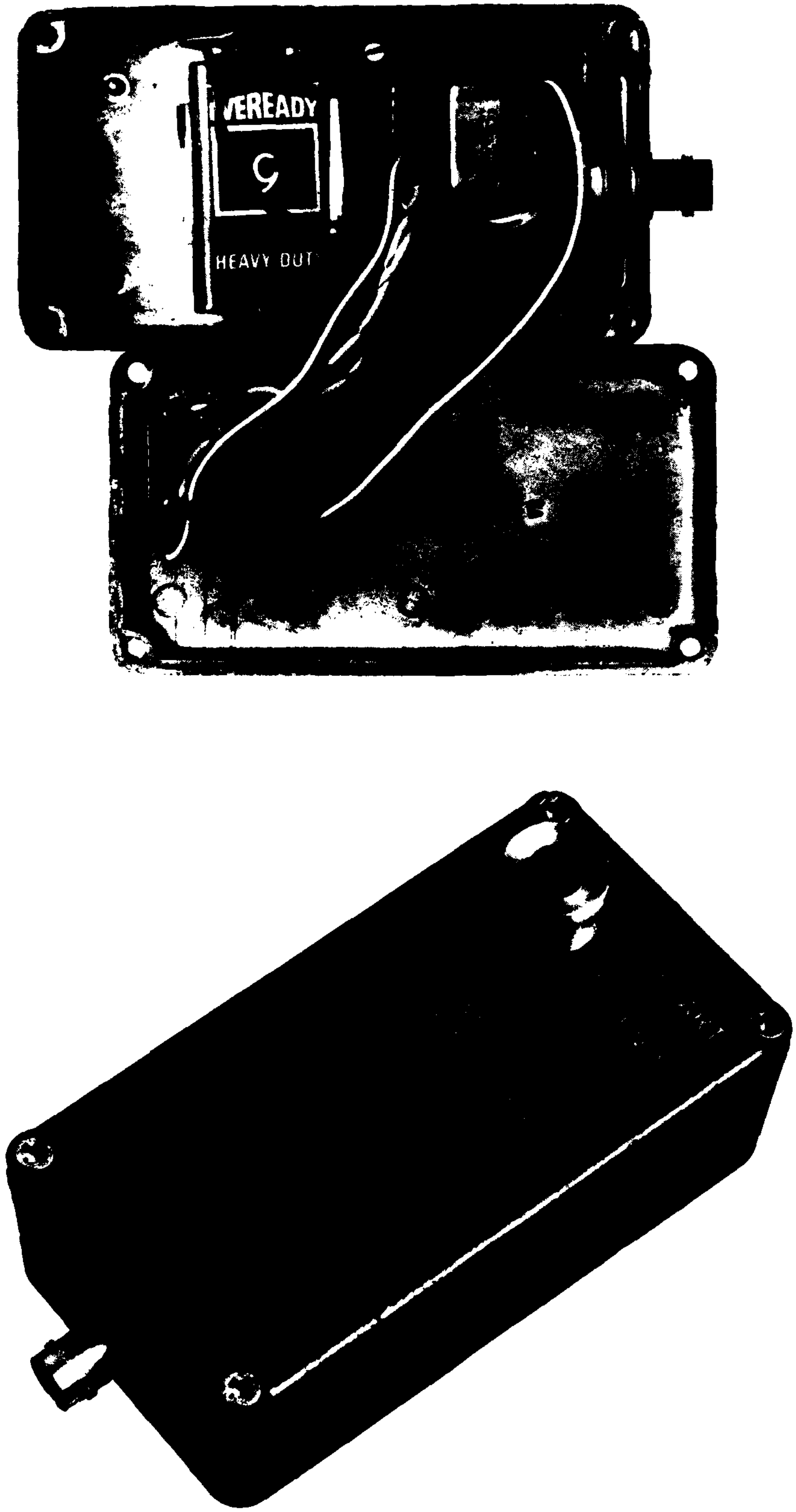

FIGURE 4 - Internal and external views of Camera Controller.

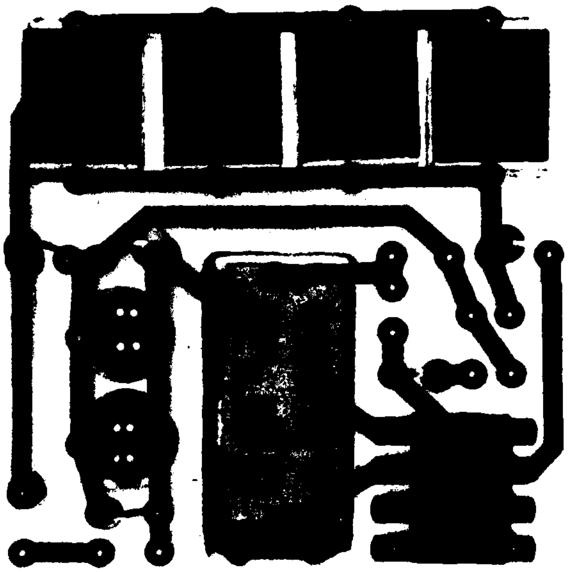

FIGURE 5 - Component layout of Camera Controller.

FIGURE 6 - Enlarged view of LED/lens assembly.

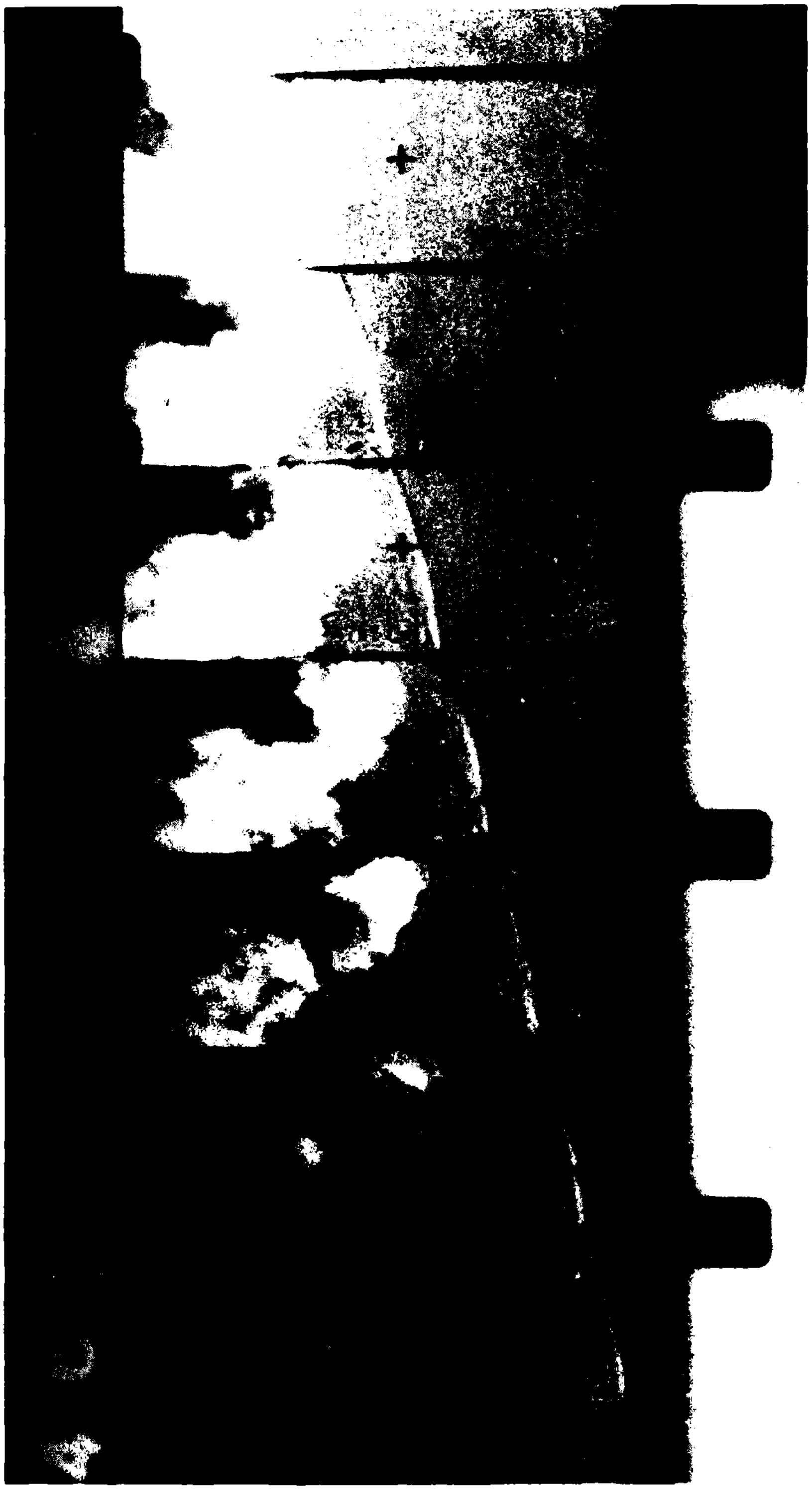

FIGURE 7 - Print from 16 mm film showing timing mark on left hand edge and event mark on right.

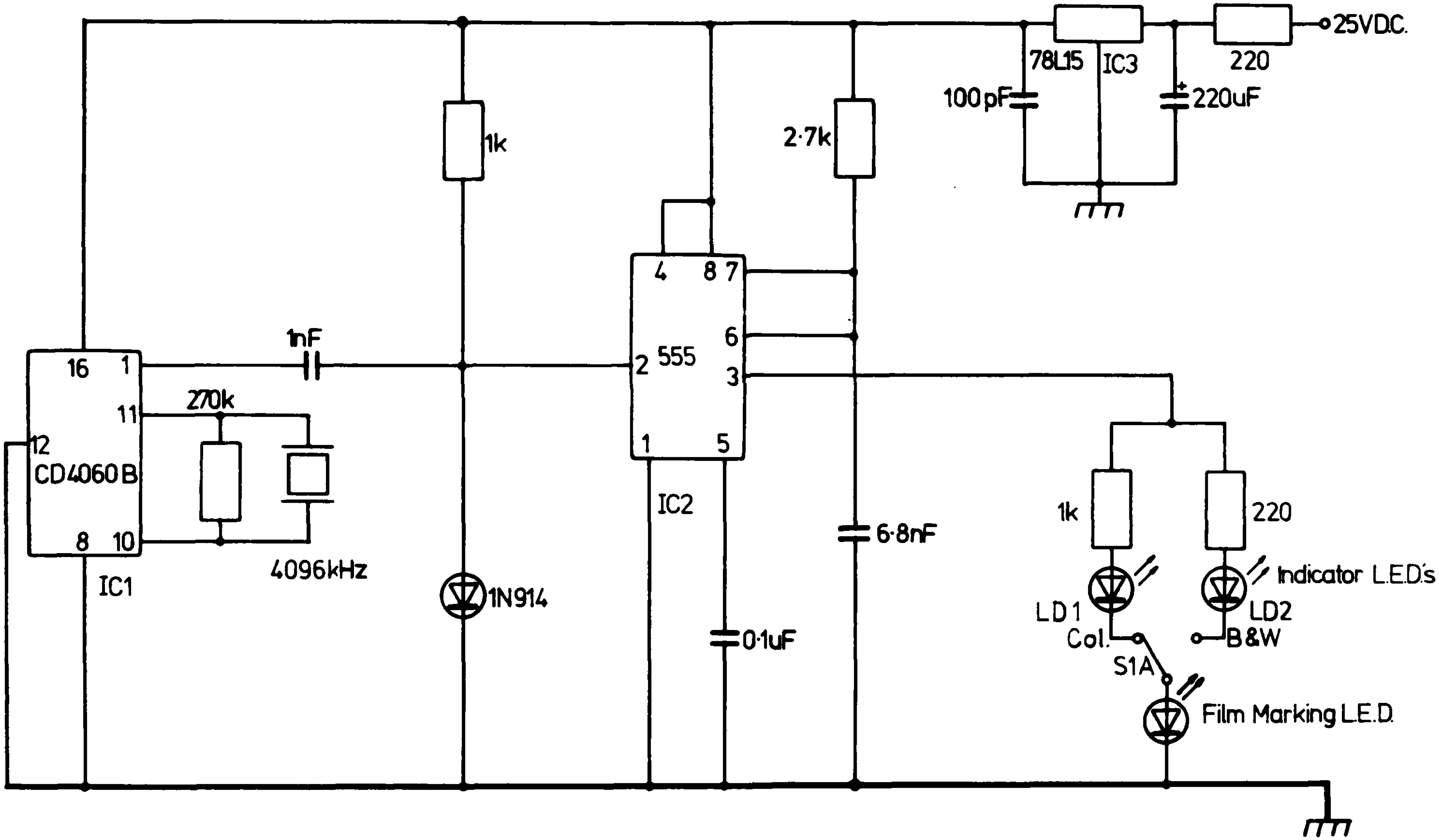

FIGURE 8 - Crystal Controlled Timing Mark Generator Circuit Diagram.

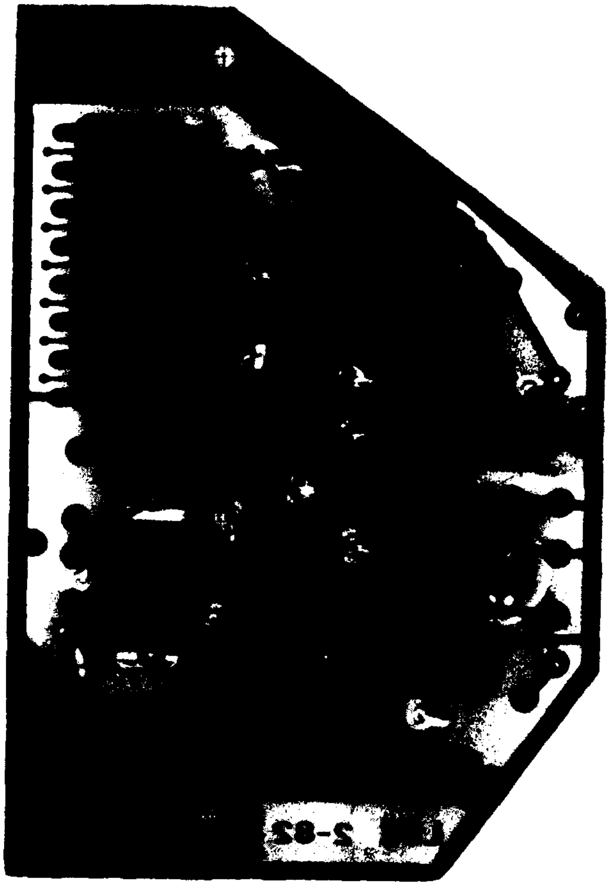

FIGURE 9 - Component Layout of Timing Mark Generator Board.

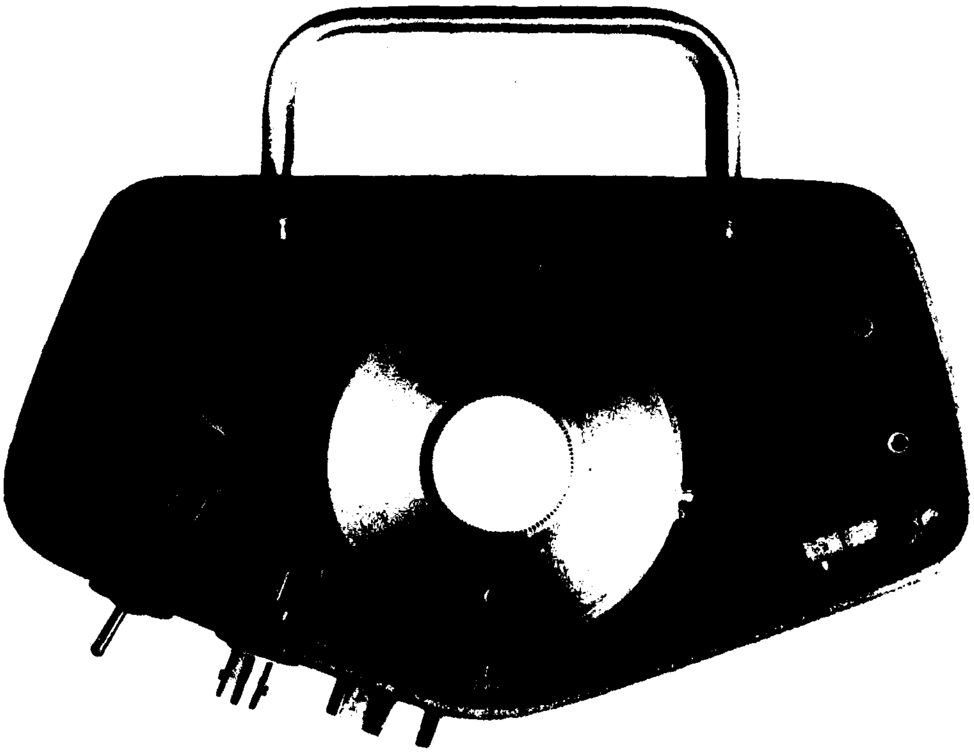

FIGURE 10 - Timing Mark Generator Board shown mounted in Hycam Optical Head.

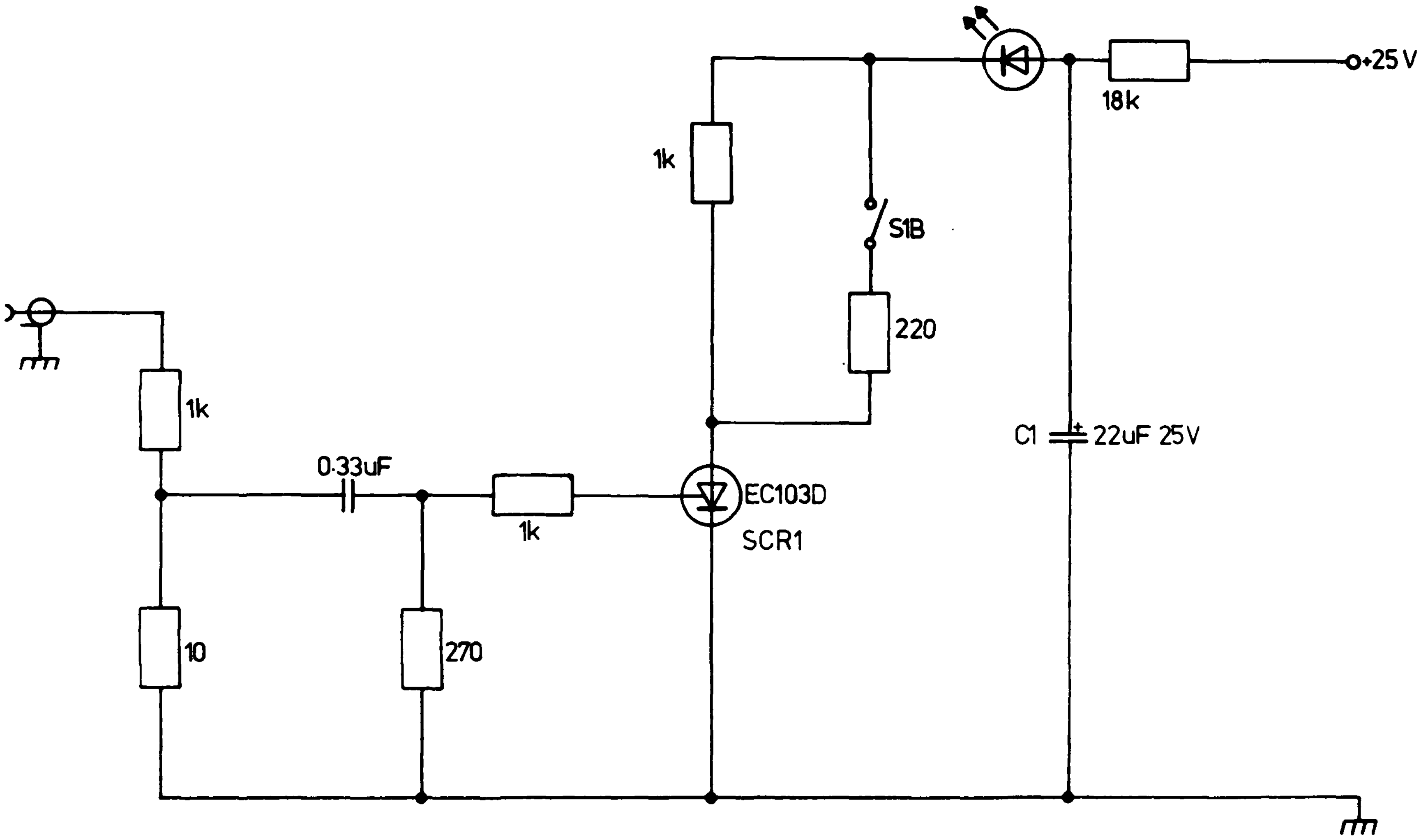

FIGURE 11 - Event Mark Generator Circuit Diagram.

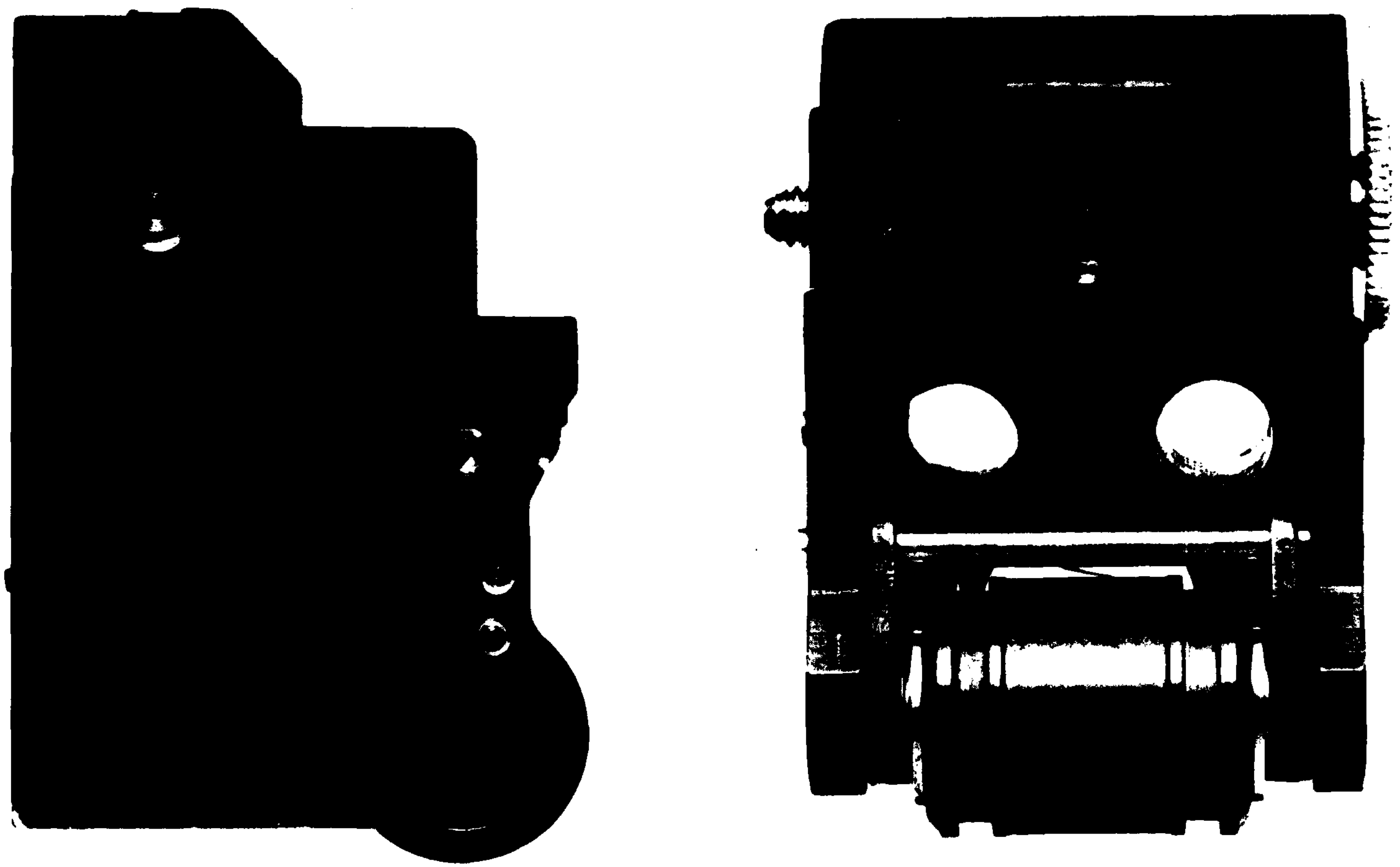

FIGURE 12 - Enlarged View of Modified Latch Block Assembly.

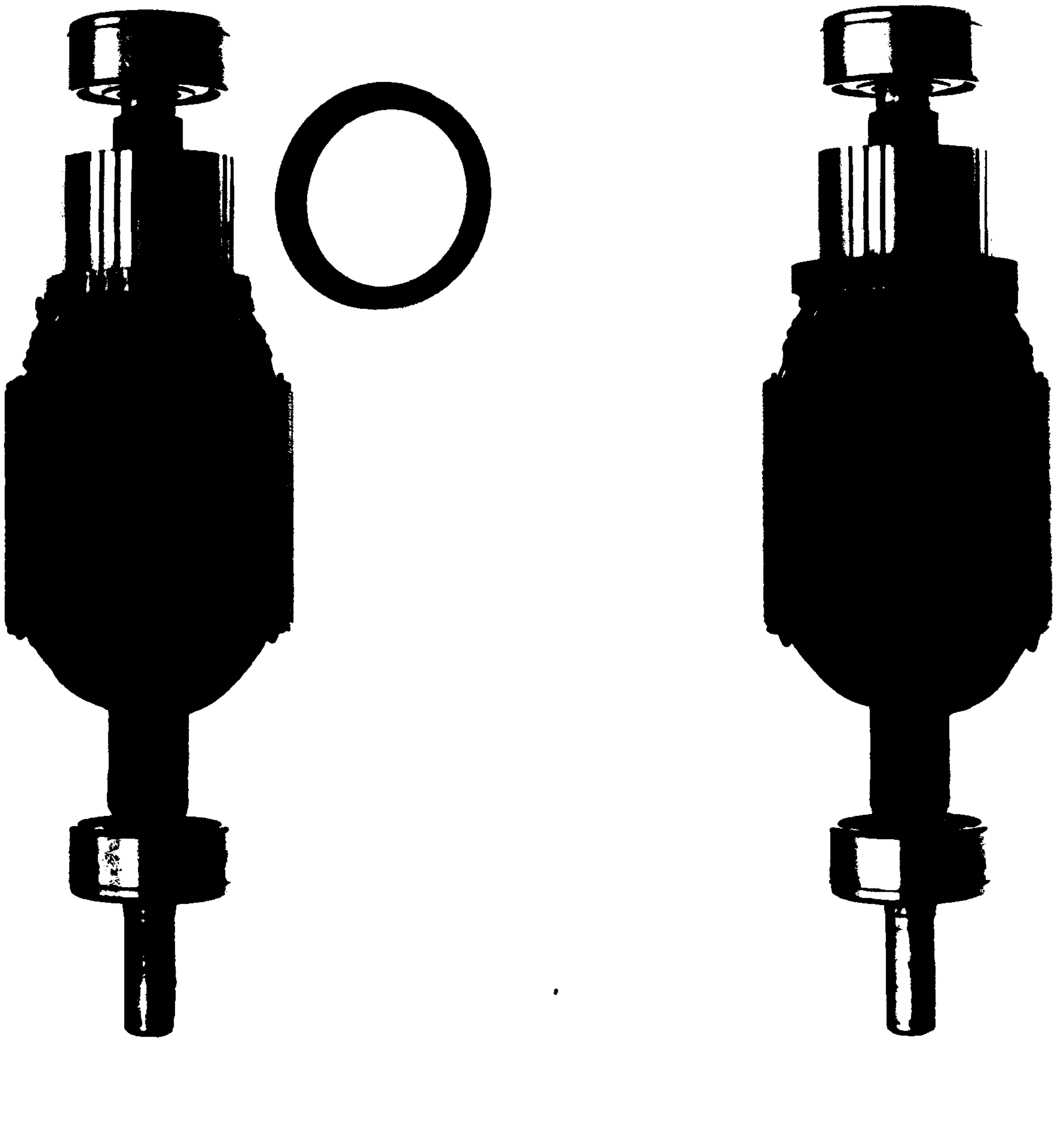

FIGURE 13 - Hycam Commutator with added "Tufnol" retaining ring.

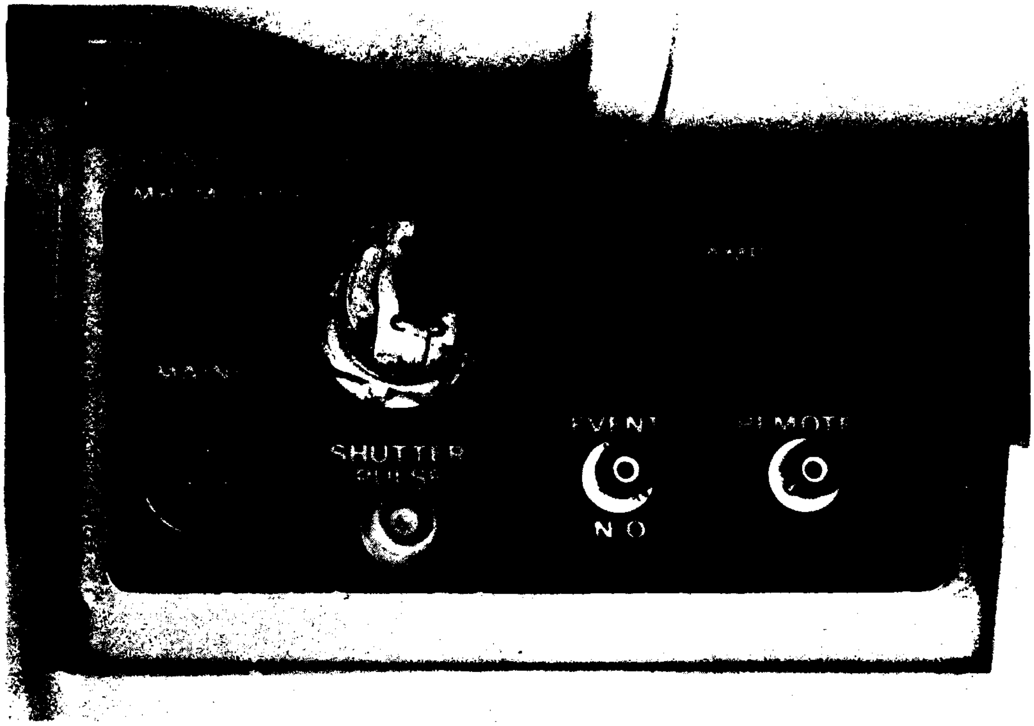

FIGURE 14 - Modified Connector Panel using isolated BNC connectors.

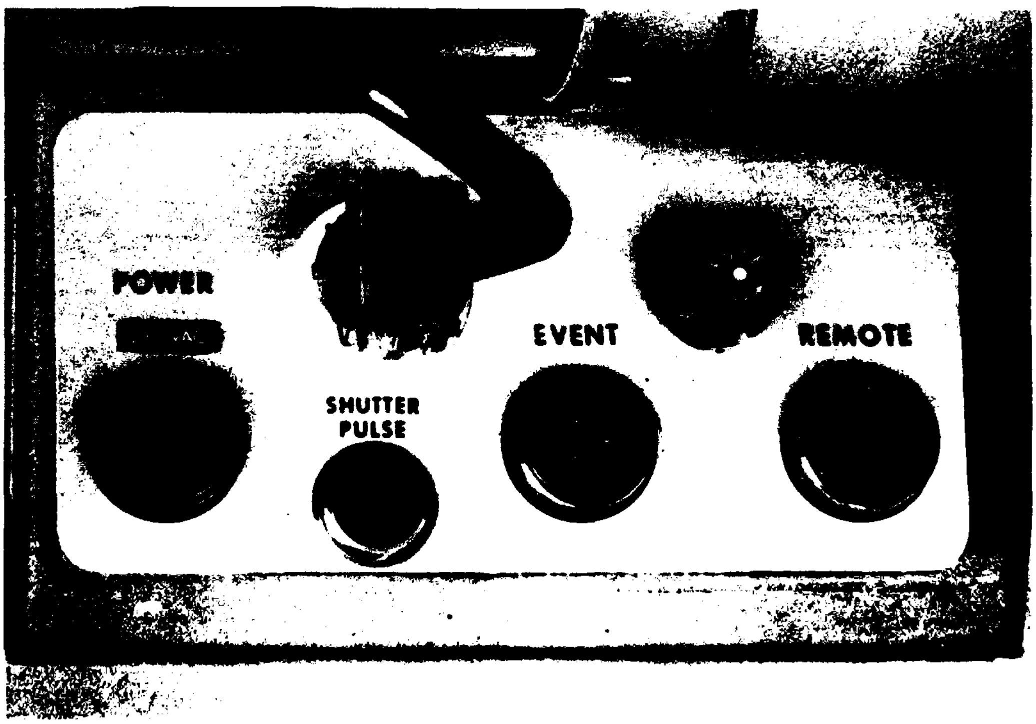

FIGURE 15 - Original Connector Panel using Multi-pin connectors.

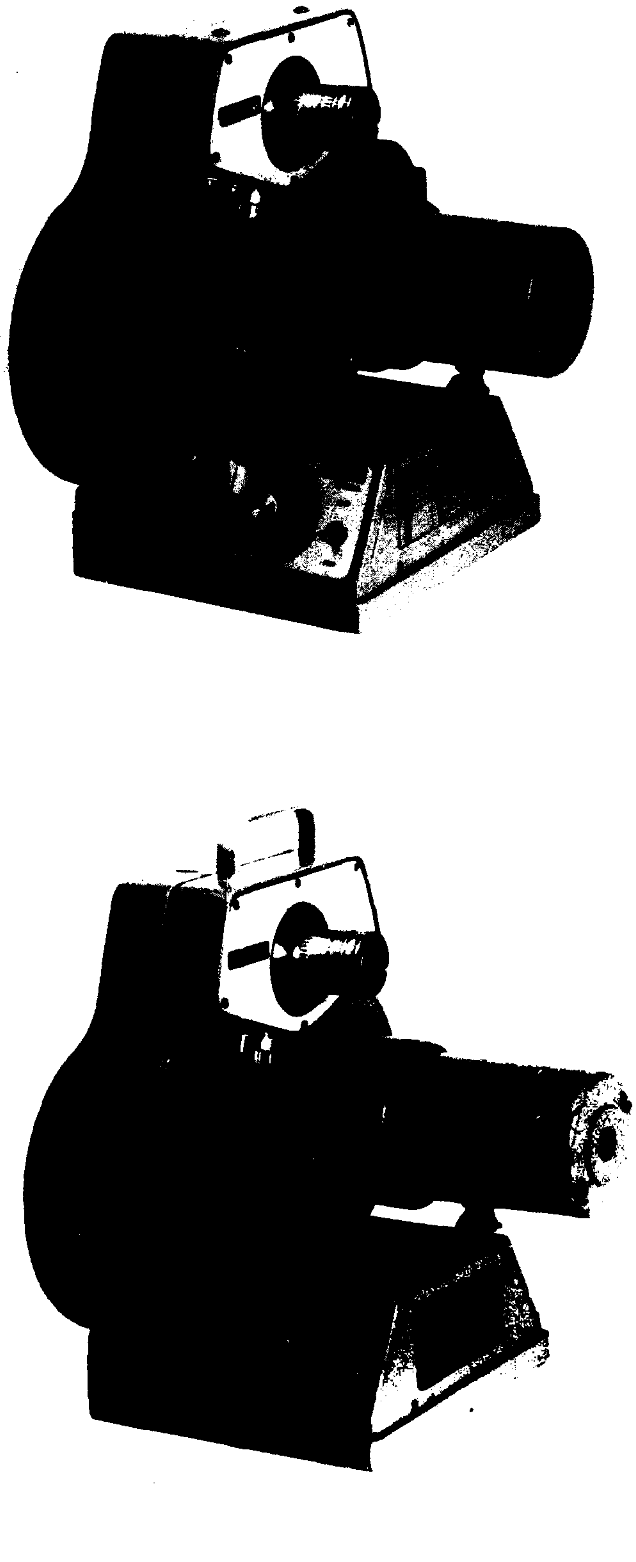

FIGURE 16 - View showing the replacement neon mains indicator and the original stop/start switch.

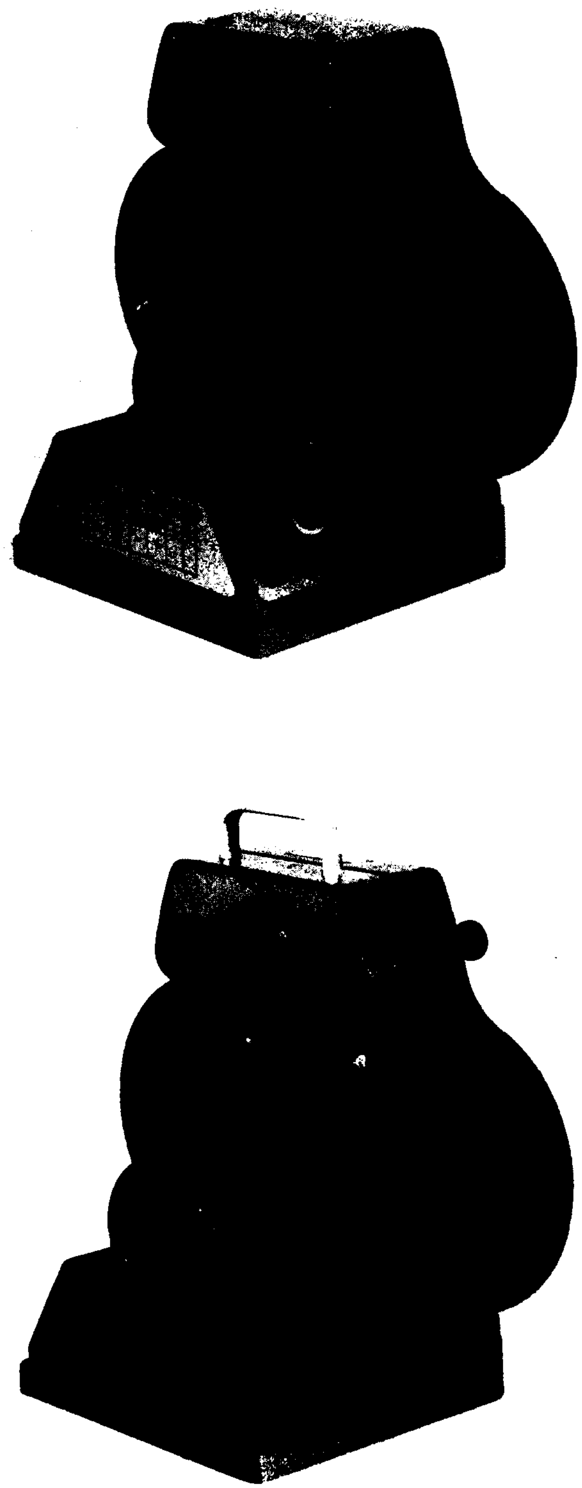

FIGURE 17 - General views of modified and unmodified Hycam Cameras.

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